Understanding crude oil import demand behaviour in Ghana

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Abstract

Crude oil importation is a major drain on the economy of Ghana, yet no study has attempted to analyse the determinants of crude oil imports. This paper brings to the fore an understanding of the key drivers of crude oil import demand. Using the autoregressive distributed lag modelling framework (ARDL), we estimate variant short-run and long-run import demand models for crude oil using time series data over the period 1980-2012. The results show that demand for crude oil is price inelastic in both the long and short term. Other important drivers of crude oil import are the real effective exchange rate, domestic crude oil production and population growth. Furthermore, real economic activity is found to be the most robust and dominant driver of crude oil demand with mixed estimates of inelastic and elastic coefficients in the short-run and long-run, respectively. Policy implications of our results are discussed.

Keywords: Crude oil demand, import, determinants, cointegration, Ghana

JEL classifications: F10, Q11, Q31, Q41, Q48

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1. Introduction

Crude oil is a major driver of businesses, manufacturing, transportation of goods and services and maritime trade at the national, regional and global level. The pursuit of higher growth rates imply need for adequate supply of crude oil and its constituent products such as gasoline, liquefied petroleum gas (LPG), kerosene among others for the domestic, industrial, agricultural and transport sectors of any economy. Since the episodes of the global oil price hikes in the 1970s and during 2007-2008 crisis period where crude oil price shot up from US$25 per barrel in January 2000 to US$134 per in July 2008 per barrel of light blend Brent crude oil (some accounts report US$147 – see Askari and Krichene, 2010), interest in the analysis of price and demand dynamics of crude oil has increased. Even though the price eased below the US$100 mark since September 2009, an upward trajectory hovering above US$100 has been evident from February 2011 till date (price as at August 2013 was US$111 per barrel; see Fig. 4 in the Appendix). Understanding the dynamics of the petroleum subsector and demand for petroleum and related products is very crucial for policy purposes in Ghana.

Ghana achieved lower middle income status in 2006 after a rebasing of the national accounts. With a chequered economic history characterized by series of fluctuating revenue windfalls and losses from commodity exports (mainly gold, cocoa and timber), and economic and structural reforms following deteriorating economic fortunes, Ghana has since the last two decades posted positive growth rates. Real gross domestic product (GDP) growth has hovered above 5% since 2003 (except 4% in 2009) hitting an all-time high of 15% growth in 2011 (see Fig. 5 at the Appendix). The rapid growth of the economy implies increased production of goods and services in various sectors of the economy with its consequent effect on energy demand, especially crude oil. Ghana is a net importer of crude oil whose price is determined on the international market. As a small and open economy, Ghana is often vulnerable to oil price shocks in the event of any significant price jumps on the world market. Even though the country has been producing oil since the establishment of the Ghana National Petroleum Corporation (GNPC) in 1987 to explore for oil (Gyampo, 2010), output from the Saltpond Fields is not in significant quantities to meet domestic demand. Hence, the genesis of Ghana's high crude oil imports. For example, in 2012 total oil production from the Saltpond field was about 105,000 barrels with daily and monthly productions averaging about 290 and 8,800 barrels, respectively (Ghana Energy Commission, 2013). Interestingly, after discovering crude oil in commercial quantities in 2007 off the coast of Cape Three

Points (dubbed the Jubilee Fields) with an estimated total reserves of between 500 million and 1.5 billion barrels, Ghana continues to import significant amounts of crude oil for electricity generation, the refinery (TOR)[2], transport sector, industry and homes (Breisinger *et al*., 2010). Ghana's petroleum production requirement far exceed the capacity of TOR with the shortfall estimated in the range of 26-30% under the assumption that TOR is operating at over 90% capacity utilization (Ghana Energy Commission, 2011). Total domestic oil consumption continues to rise while production has remained largely constant from 1980 until 2010 when commercial production came upstream with an estimated 120, 000 barrels per day. From 16,000 barrels per day in 1980, crude oil consumption stands at 64,000 barrels per day in 2012 (an average of approximately 5% growth over the period – see Fig. 1 and Fig. 2). In 2009 and 2010 alone, crude oil consumption grew by about 21.4% and 20.2%, respectively. TOR refines all the crude oil needs of Ghana, except for power generation. It is a hydro skimming plant with a Crude Distillation Unit (CDU) of production capacity of 45,000 barrels per day and a 14,000 Residual Fluid Catalytic Cracker (RFCC) unit to process residual fuel oil (RFO), a by-product of the crude oil processed by the CDU, into diesel, gasoline and LPG (Ghana Energy Commission, 2011). The petroleum subsector within the entire energy sector has been undergoing deregulation with oversight responsibility by the National Petroleum Authority (NPA)[3], the regulator.

[2] Tema Oil Refinery (TOR) is the only refinery plant in Ghana.

[3] In 2005, Parliament passed an Act 691 which mandated the National Petroleum Authority, (NPA), to regulate the downstream sector of the petroleum Industry (i.e. from when crude oil or petroleum products enter the shores of Ghana till it is discharged either to the Refinery or to another depot in the country, the distribution of the petroleum products that are refined or brought into the country). We also have the mandate to regulate every single Petroleum Service Provider (PSP) that provides its service in the Industry. (NPA website). Available at http://www.npa.gov.gh/npa_new/faqs.php

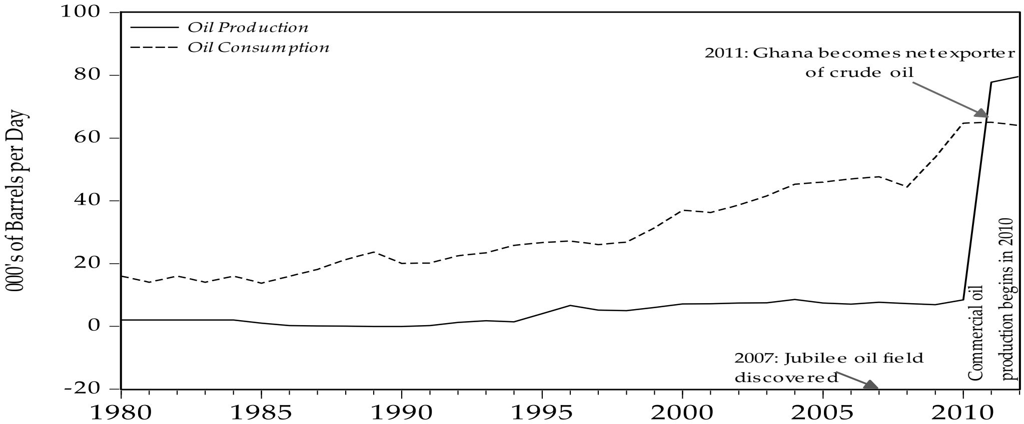

Fig. 1. Ghana's crude oil production and consumption (1980-2012)
Data source: International Energy Statistics, U.S. EIA database

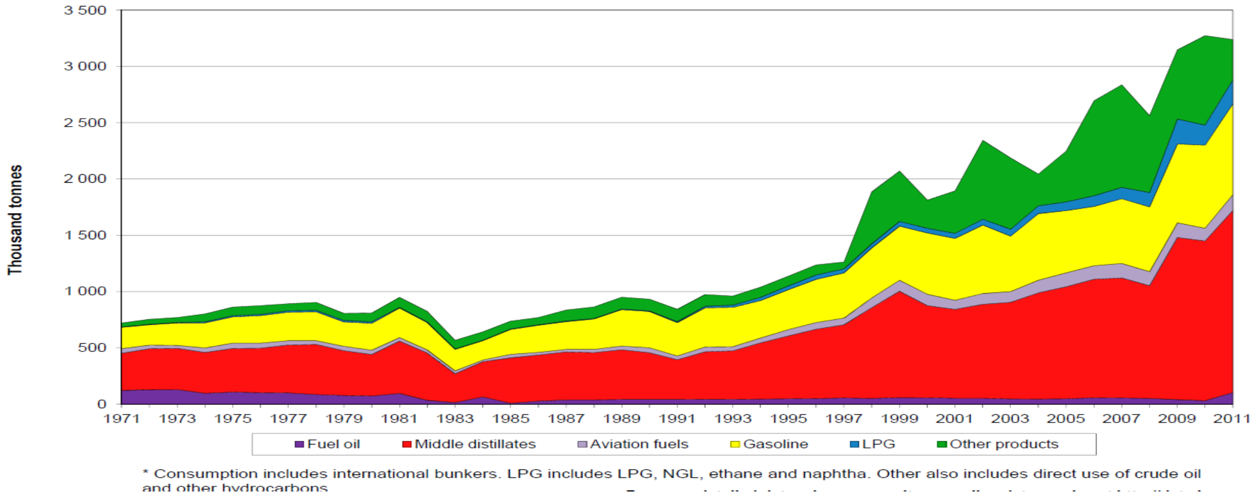

Fig. 2. Consumption of oil products
Source: IEA Energy Statistics, 2013

Pricing of petroleum products is done using an automatic price adjustment formula that reflects changes on the domestic market any time world crude oil prices change. Government subsidies (a non-targeted strategy) on petroleum products such as kerosene, diesel, gasoline and LPG as a cushioning against full pass-through of global crude oil price hikes to consumers, continues to generate debate among political entities, industry players and the public.

At the aggregate level, crude oil constitutes a significant share of total imports and a major contributor to the worsening trade balance and overall balance of payment (BOP) position (Table 1 and Fig. 3). Crude oil imports have increased from US$307 million in 1980 to US$3.2 billion in 2011 (about 11% annual average growth over the last 30 years). Daily crude oil imports for power generation for domestic and commercial uses amounts to US$1m (equivalent to US$30m per month) – World Bank (2013). Another worrying trend from the data is that Ghana continues to finance significant share of the crude oil import bills from export earnings. For example, in 2007, about 50.2% of the country's export earnings were used to finance crude oil purchases (Table 1). Between 2000 and 2005, crude oil imports alone accounted for more than 10% of Ghana's GDP.

The huge oil import bill continues to be a drain on the foreign reserve and BOP of the economy. The direct and indirect effects on other sectors of the economy cannot be overemphasized. The International Monetary Fund's (IMF) forecast shows that independent of Ghana's current status as an oil exporting country, the end to or downsizing of the thirst for crude oil importation is not in sight, at least in the medium term. It is estimated that Ghana would continue crude oil imports in excess of US$3 billion per annum between 2012 and 2018 (Fig. 3). Imports are mainly from OPEC (Nigeria) and non-OPEC (Equatorial Guinea) suppliers. In 2011, for example, Ghana's crude oil supplies came from Nigeria.

Table 1. Trends in oil imports and related indicators (in US$ million unless otherwise stated)

	2000	2005	2006	2007	2008	2009	2010	2011**	2012
Merchandise Imports (f.o.b)	2 766.6	5 347.3	6 753.7	8 066.1	10 268.5	8 046.3	10 922.1	15 837.7	17 763.2
Non-oil import	2 246.4	4 217.9	5 107.5	5 971.1	7 911.8	6 557.3	8 686.2	12 672.3	14 432.6
Oil import	520.1	1 129.4	1 646.2	2 095.0	2 356.7	1 489.0	2 235.9	3 165.4	3 330.2
Oil import/Non-oil import	23.2	26.8	32.2	35.1	29.8	22.7	25.7	25.0	23.1
Merchandise Exports (f.o.b)	1 936.3	2 802.2	3 726.7	4 172.1	5 269.7	5 839.7	7 960.1	12 785.4	13 542.8
Merchandise Trade Balance*	830.2	2 545.1	3 027.0	3 894.0	4 998.8	2 206.6	2 962.0	3 052.3	4 220.4
Oil import/Trade Balance (%)	62.6	44.4	54.4	53.8	47.1	67.5	75.5	103.7	78.9
Oil import/Total Import (%)	18.8	21.1	24.4	26.0	23.0	18.5	20.5	20.0	18.7
Oil import/Total exports (%)	26.9	40.3	44.2	50.2	44.7	25.5	28.1	24.8	24.6
Nominal GDP($ million)	4 982.8	10 731.9	20 410.3	24 757.6	28 528.0	25 977.9	32 174.2	39 565.0	40 710.8
Oil import/GDP (%)	10.4	10.5	8.1	8.5	8.3	5.7	6.9	8.0	8.2

Sources: Bank of Ghana; WDI

Note: * Deficit trade balance; ** Gas imports from Q1 added to oil imports

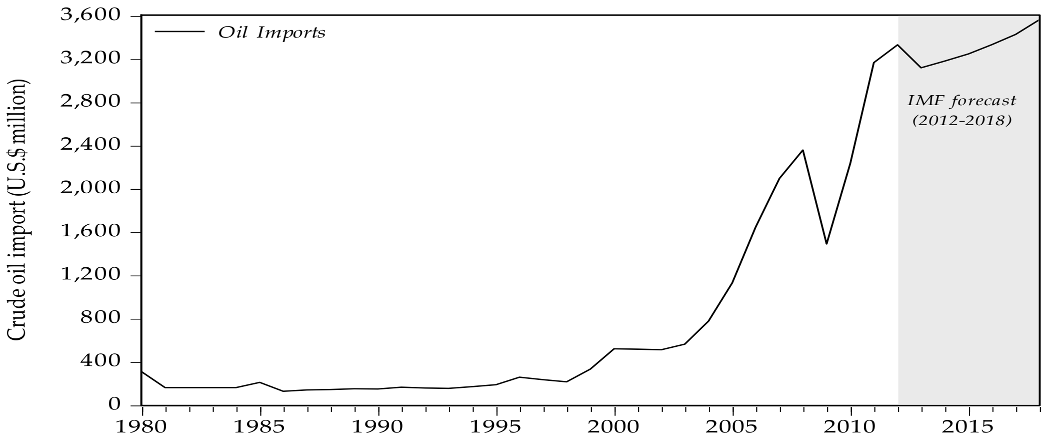

Fig. 3. Trends in Ghana's crude oil imports (US$ million)
Data source: World Economic Outlook, IMF April, 2013

There are several studies at the national, regional and global scale investigating crude oil import demand. However, despite the importance of oil import in the economy of Ghana, no study has been conducted that estimates income and price elasticities among other indicators to explain oil import demand behaviour. With a view to influencing policy-making with regard to energy use and related matters, this paper empirically analyses the determinants of crude oil demand in Ghana. It makes significant contribution to the literature since it is the first study to bring to the fore what drives Ghana's import demand for crude oil. We use the autoregressive distributed lag model (ARDL) to empirically estimate both short-run and long-run price and income elasticities of oil import in Ghana. We also control for other relevant variables such as the real effective exchange rate (REER), domestic crude oil production and population growth rate.

The rest of the paper is structured as follows. Section 2 presents a brief literature review. We discuss data issues and the econometric approach in Section 3, while the analysis of the empirical results is presented in Section 4. The paper concludes with some policy implications in Section 5.

2. A Brief Literature Survey

There are a plethora of empirical studies on energy demand in developed, emerging, and developing countries. Several empirical papers have investigated the determinants of aggregate demand or disaggregated components of different energy types. Studies on the demand for crude oil have seen significant growth in recent years. Perhaps, recent hikes in global oil prices could explain current growing interest in the subject by researchers. We review a few of the recent studies on crude oil demand behaviour.

Recent studies include among others Ghouri (2001), Krichene (2002), Cooper (2003), Alves and Bueno (2003), Dées et al. (2007) and Altinay (2007)[4]. Results from these studies are often mixed. While some find inelastic demand with respect to both oil price and real income, others reveal price inelastic and income elastic oil demand coefficients in their long- and short-run models. Altinay (2007) estimate the short-run and long-run elasticities of crude oil demand in Turkey using the autoregressive distributed lag model (ARDL). The results suggest elastic price and income coefficients of -0.81 and 0.61, respectively. Narayan and Smyth (2007) in another study of 12 Middle East countries finds that the income elasticity variable differ across countries but at the panel level, consumers are insensitive to price changes. They find that demand for oil in the Middle East is significantly driven by income.

Zhao and Wu (2007) examine the factors that determine oil imports into China by considering price of crude oil, domestic energy production (including crude oil), industrial output and total traffic volume as potential determinants. They find a significant, positive and inelastic price elasticity relationship with oil imports. In other models estimated, crude oil price appear to play a trivial role in China's oil imports. The most important factors found to drive oil import demand in China are value added industrial output, local total energy output (significant substitution effect) and the transport sector (total freight traffic and passenger traffic elasticities are 1.92 and 3.60, respectively). Similarly, Jabir (2009) finds that the US GDP plays a leading role together with domestic oil production in determining oil imports. Another study on China by Xiong and Xu (2009) identified oil, GDP, population growth and share of the industrial sector in GDP as the drivers of crude oil demand.

Studies by Pedregal et al. (2009) and Sa'ad (2009) further supports Narayan and Smyth (2007) where they find that the main driver of demand for crude oil products is real income rather than price in Spain and Indonesia. The effects of income, price and fuel efficiency (proxied by a stochastic time trend) is quantified for UK transport oil demand for the period 1960-2007. Again, the impact from real income is found to be relatively larger than price and efficiency with elasticities 0.6, -0.1 and -0.3, respectively. Iwayemi et al. (2010) show that petroleum products are both price and income inelastic in Nigeria.

[4] Others include Narayan and Smyth (2007), Akinboade et al. (2008), Ghosh (2009), Sa'ad (2009), Pedregal et al. (2009), Broadstock and Hunt (2010), Askari and Krichene (2010), Ziramba (2010), Dargay and Gately (2010), Moore (2011), Ediger and Berk (2011), Sentenac-Chemin (2012).

Tsirimokos (2011) estimate price and income elasticities for crude oil demand in Sweden, Denmark, Spain, Portugal, Turkey, Finland, Italy, Germany, USA and Japan. Using Nerlove's partial adjustment model, the results show both price and income elasticities are more inelastic in the short-run than in the long-run. Estimates for Sweden and Denmark for example show price and income elasticities of -0.05, 0.38 and -0.04, 0.63, respectively. Other studies reviewed have either corroborated earlier papers or given mixed results (see for example Bhattacharyya and Blake, 2009 for MENA countries). Table 2 summarizes long-run results of some selected recent studies of crude oil/gasoline demand elasticities.

Table 2. Selected empirical long-run elasticities

Study	Country(ies)	Price elasticity	Income elasticity	Modelling technique	Study period
Ghouri (2001)	USA	-0.045	0.989	Almon polynomial	1980-1999
	Canada	-0.06	1.08	distributed lag model	
	Mexico	-0.05	0.84		
Krichene (2002)	World	-0.005 -0.13	0.6 1.80	Simultaneous equation model (SEM)	1918-1999
Cooper (2003)	USA (+ 22 other countries)	-0.06	1.05	Nerlove's partial adjustment	1979-2000
Alves & Bueno (2003)	Brazil	-0.465	0.122	Engle and Granger cointegration	1974-1999
Dées et al. (2007)	World		0.17 0.98	Quarterly macroeconometric model	1984:1-2002:2
Altinay (2007)	Turkey	-0.18	0.61	ARDL	1980-2005
Narayan & Smyth (2007)	Panel of 12 Middle East countries	-0.015	1.014	DOLS & FMOLS	1971-2002
Akinboade et al. (2008)	South Africa	-0.47	0.36	ARDL	1978-2005
Ghosh (2009)	India	-0.63	1.97	ARDL	1970-2006
Sa'ad (2009)	Indonesia	-0.15 -0.16	0.86 0.88	ARDL	1970-2005
Pedregal et al. (2009)	Spain	-0.051	0.441	Unobserved components model (UCM)	1984:1-2006:12
Broadstock & Hunt (2010)	UK	-0.12	0.57	Structural time series model	1960-2007
Askari & Krichene (2010)	World	-0.002	0.020	Simultaneous equation model (SEM)	1970Q1-2008:Q4
Ziramba (2010)	South Africa	-0.147	0.429	Johansen cointegration analysis	1980-2006
Dargay & Gately (2010)	30 OECDs	-0.60	0.80	Reduced-form model with country fixed effects	1971-2008
Moore (2011)	Barbados	-0.552	0.91	ARDL	1998:1-2009:12
Sentenac-Chemin (2012)	US	-0.28	0.60	Cointegration technique	1978-2005

3. Methodology

Following from the standard framework of modelling energy demand which is derived from the Marshallian demand theory for goods and services, we formulate our basic crude oil import demand model, consistent with the literature, as a function of real income and international price of crude oil. Thus the real value of crude oil import is specified as a function of real GDP and real price of oil for Ghana as follows:

$$OilM_t = f(OilP_t, GDP_t) \tag{1}$$

where $OilM_t$ denote the value of crude oil import in US$ million, GDP_t is the value of real economic activity (proxied by real GDP in constant prices and in US$ million). Crude oil price, OilP_t, is the average world oil price comprising the UK Brent, Dubai Fateh and West Texas Intermediate (WTI) of the US in US$ per barrel. It is deflated by the world consumer price index (2005=100) to obtain oil price in real terms. Equation (1) is expressed in logarithmic form as follows:

$$lnOilM_t = \beta_0 + \beta_1 lnOilP_t + \beta_2 lnGDP_t + \varepsilon_t \tag{2}$$

where all the variables are as previously defined except ε_t , error term assumed to satisfy all the residual regression assumptions of no serial correlation, homoscedasticity, normality and correct model specification. Since the model is formulated in logarithmic form, the estimated parameters represent elasticities. Standard demand theory posits a negative relationship between quantity demanded and the price of a good Thus, we expect that a higher price of crude oil will dampen demand for crude oil, ceteris paribus $(\beta_1 < 0)$. Conversely, higher income levels are expected to boost economic activities and hence higher demand for crude oil. Therefore we expect import demand for crude oil to respond positively to real income $(\beta_2 > 0)$. As an extension of the basic model (2), we include additional variables such as Ghana's real effective exchange rate (REER), domestic crude oil production (Oilprd) and the rate of growth of population (POPG) as controls for other potential determinants of aggregate crude oil import demand. We then estimate another model as:

$$lnOilM_t = \alpha_0 + \alpha_1 lnOilP_t + \alpha_2 lnGDP_t + \alpha_3 X_t + \nu_t \tag{3}$$

Again, all other variables except X_t which denote a vector of additional control variables such as REER, Oilprd and POPG, and ν_t (error term) remain defined as previously. An alternative variable used in the literature in place of POPG is the urban growth rate of the country. In our case, the two variables did not alter the results in any significant way. The inclusion of REER in the demand equation is important because oil price on the world market is quoted in US dollars. Further, any change in the exchange rate of the local currency against the US$ affect the domestic price of oil and the real value of financial assets/wealth and hence the demand for oil. Since Ghana is generally a net importer of crude oil and a price-taker, any changes in the exchange rate will affect demand for crude.[5] The REER variable is defined such that an increase implies real appreciation of Ghana's currency (GH¢) against the US$. Therefore, real appreciation of the local currency against the US$ should stimulate aggregate demand and hence a higher demand for crude oil. Also, increased domestic crude oil production could have a substitution effect for imported crude, hence we expect it to have a negative effect on crude oil demand. Due to degrees of freedom reasons, other macroeconomic variables such as international/foreign reserves, interest rate among others are excluded from the model.

We estimate the specified models using annual time series data for the period 1980-2012. All the data used in this paper are sourced from the International Financial Statistics (IFS), Fiscal Affairs Department database and World Economic Outlook of the IMF, World Development Indicators (WDI) of the World Bank, Ghana Statistical Service, and the Energy Information Administration (EIA) of the US Department of Energy.

In estimating the short-run and long-run determinants of crude oil import demand, we use the ARDL modelling approach by Pesaran et al. (2001). This modelling approach involves estimating a dynamic model by incorporating the lags of the dependent variables as well as the lagged and contemporaneous values of the independent variables. The short-run components are then estimated directly while the long-run effects are obtained indirectly. In this study, we utilize the bounds test for cointegration analysis within the ARDL framework. The advantage of the ARDL modelling approach over other cointegration procedures is that it has better finite sample properties unlike the Engle and Granger two-step and Johansen maximum likelihood approaches which suffer from small sample bias. Secondly, it can be applied irrespective of the order of integration of the series under consideration. That is, it is applicable on all

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[5] Askari and Krichene (2010) summarize succinctly the effect of the exchange rate in the demand model as follows: "The exchange rate is an asset price, defined as the price of one unit of foreign exchange in terms of units of local currency. Changes in the exchange rate are different from changes in a tradable good price (e.g., oil price). While changes in one good's price affect only the relative price of that good, a change in the exchange rate affects the price of all tradables and the relative price of tradables to nontradables; it also changes the real value of monetary assets and the real value of net holdings of foreign currency-denominated assets, and therefore has a wealth effect. For instance, holding money supply fixed, the real value of money declines in case of currency depreciation, and increases in case of appreciation, thus depressing, or stimulating a country's aggregate demand".

$I(1)$ or $I(0)$ series or a combination of the two; hence pre-testing for the order of integration of the variables is not a pre-requisite.

Even though the ARDL framework does not require pre-testing of the variables for unit root, we need to ascertain the presence or otherwise of higher order integrated series such as $I(2)$ which can invalidate the modelling process.

We implement the ARDL approach in two main steps. As a precursor to estimating the short-run and long-run elasticities we first test for cointegration to ascertain whether there is any long-run equilibrium relationship among the variables in the model to be estimated. If cointegration is established, we then estimate the long-run coefficients and the associated short-run parameters via the ARDL framework. The ARDL framework for equation (2) involves estimating the following unrestricted error correction model (UECM):

$$\begin{aligned}\Delta lnOilM_t &= \lambda_0 + \sum_{i=1}^{n}\lambda_1 \Delta lnOilM_{t-i} + \sum_{i=0}^{n}\lambda_2 \Delta lnOilP_{t-i} + \sum_{i=0}^{n}\lambda_3 \Delta lnGDP_{t-i} + \sum_{i=0}^{n}\lambda_4 \Delta X_{t-i} \\ &+ \eta_1 lnOilM_{t-i} + \eta_2 lnOilP_{t-i} + \eta_3 lnGDP_{t-i} + \eta_4 X_{t-i} + \varpi ECM_{t-1} + \mu_t\end{aligned} \tag{4}$$

where Δ is the difference operator and all other variables are as earlier defined and the terms λ_1, λ_2, λ_3 and λ_4 are the short-run coefficients while η_1, η_2, η_3 and η_4 denote the long-run elasticities. ECM_{t-1} is the error correction term which measures the speed of adjustment to long-run equilibrium following a shock to the system.

Cointegration among the variables is confirmed within the bounds test framework by testing the joint null hypothesis that the coefficients of the lagged level variables are significantly zero in equation (4). That is, if the null hypothesis represented by $H_o : \eta_1 = \eta_2 = \eta_3 = \eta_4 = 0$ is rejected, then the hypothesis of no cointegration is rejected against the alternative $H_1 : \eta_1 \neq 0, \eta_2 \neq 0, \eta_3 \neq 0, \eta_4 \neq 0$ of cointegration using either a Wald or an F-test. We use the F-test in this paper. This is an F-test with a non-standard asymptotic distribution which is dependent on whether the included variables in the ARDL model are either $I(0)$ or $I(1)$, number of regressors, whether an intercept and/or a trend is included in the ARDL model, and the sample size (Pesaran et al. 2001; Ghosh, 2009). Pesaran et al. (2001) then provides two sets of critical values in testing for cointegration when the underlying variables are $I(1)$ or $I(0)$. If the calculated F-statistic exceeds the upper critical bound at some significance level, then we can safely reject the null hypothesis of no cointegration. Conversely, if the calculated F-statistics falls below the lower critical bound, we fail to reject the null of no cointegration. If it however falls within the band, then our inference is inconclusive. In either of the models to be estimated, we denote the null hypothesis by $F_{OilM}(\cdot)$.

4. Empirical results

4.1. Unit root results

We use the Phillips-Perron (PP)[6] unit root procedure to test for non-stationarity of the underlying time series for the study. The PP procedure tests the null hypothesis of unit root against the alternative of stationarity of the series. Table 3 shows the results of the PP test. Including an intercept in the PP regression, the results show that all the variables contain unit root. Stationarity is however achieved after first differencing of the variables. Hence, we can conclude that all the variables are integrated of order one (i.e. $I(1)$), an indication of possible long-run relationship among the variables.

Table 3. Phillips-Perron (PP) test

Variables	Level	First Difference
lnOilM	0.0734	-6.6309***
lnOilP	-0.9390	-4.9609***
lnGDP	3.6440	-3.0379**
lnREER	-1.3721	-5.8032***
lnOilPrd	-0.7136	-5.2435***
POPG	-1.7525	-3.8722***

Note: ***,** denote rejection of null hypothesis of unit root at the 1% and 5% levels, respectively. Test includes intercept. Critical values are based on MacKinnon (1996) one-sided p-values.

4.2. Results of cointegration test

The results for the bounds test for cointegration relation are reported in Table 4. We test for cointegration using four different specifications. The results show the existence of long-run equilibrium relationship in the case where oil import demand is modelled as a function of only oil price and real output. Here, the *F*-statistic of 6.07 exceeds the upper critical bounds at both the 5% and 10% levels. Thus, oil price and economic activity can be said to be long-run drivers of crude oil demand in model (1). The inclusion of

[6] The Phillips-Perron (1988) test is an alternative (nonparametric) method of controlling for serial correlation when testing for a unit root.

additional variables also reveal a significant cointegration relationship between crude oil demand and oil price, real GDP and a combination of either real effective exchange rate, domestic crude oil production and/or population growth. Hence, we can conclude that international oil price, real output, a measure of Ghana's international competitiveness (REER) and the rate of population growth are long-run drivers of real crude oil import demand in Ghana. We then proceed to estimate the long-run elasticities and the associated error-correction models in the next section.

Table 4. Bounds test for cointegration

Dependent variable	*F*-statistics	Critical bounds			
		5%		10%	
		I(0)	*I*(1)	*I*(0)	*I*(1)
$F_{OilM}(OilM \mid OilP, GDP)$	6.07**	4.38	5.57	3.50	4.57
		3.36	4.78	2.75	3.99
$F_{OilM}(OilM \mid OilP, GDP, REER, POPG)$	8.14**				
$F_{OilM}(OilM \mid OilP, GDP, REER, OilPrd)$	7.49**				
$F_{OilM}(OilM \mid OilP, GDP, REER, OilPrd, POPG)$	6.18**	3.09	4.54	2.57	3.82

Note: ** denote statistical significance at the 5% level.

4.3. Estimated long-run and short-run results

The results of the estimated long-run and short-run elasticities are reported in Tables 5 and 6, respectively. As a precursor to interpretation of the estimated coefficients, we assess the appropriateness of our short-run model (error correction model) for our analysis. The estimated coefficients of the error correction terms (ECM_{t-1}) are correctly signed (negative) and statistically significant. This implies that following any shocks to the models, long-run equilibrium could still be attained or returned to through an adjustment process. Specifically, a 1% shock to say model (3) implies an annual adjustment in long-run disequilibrium by 43%. That is, 43% of previous period disequilibrium can be corrected in the current period. Additionally, our results show that real oil import demand is explained to a large extent by variations in its determinants with an R^2 ranging between 73% and 88%. Diagnostic tests applied on the residuals of the short-run model confirm that the models are well behaved with respect to serial correlation, correct functional form, normality as well as constant variances. Lastly, stability tests on the parameters were assessed using Brown et al.' (1975) cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of residuals (CUSUMQ). In all the estimated models, both CUSUM and CUSUMQ tests indicate parameter stability in that the estimated statistics of each test falls within the 5% critical bounds[7].

In the long-run, real import demand for crude oil is less responsive to real international crude oil price. That is, import demand for crude oil in Ghana is price inelastic in both the long-run and short-run. As depicted in Table 5, there is a significant inverse relationship between oil price and crude oil import demand, suggested by models (2) and (4). This is consistent from demand theory which posits a declining demand to higher prices of goods and services. Albeit negative, oil price is statistically not significant in models (1) and (3). In the case where response of crude oil demand is significantly driven by changes in oil price, we see that a 10% hike in oil price on the international commodities market would imply a depressing effect on import demand for crude oil between 3.3% and 4.5% from models (2) and (4) respectively. This result is not surprising given that until 2010 when commercial oil production began in Ghana and subsequent exportation of crude oil to the international market, the country has historically been a net importer of crude oil. Further, being a small open economy and a price-taker, Ghana significantly continues to adjust to any price hikes on the crude oil market. Noteworthy is the fact that even with her current status as a net exporter of crude oil, government still continues to import all the petroleum requirements of the country from Nigeria and Equatorial Guinea. Indeed, Ghana's Ministry of Energy and Petroleum Resources and for that matter government, makes a strong case for why Ghana should not source her crude oil from the Jubilee Fields given the quality of crude oil. According to the Ghana Energy Commission (2011), "…we do not expect our country Ghana to source her crude oil from the Jubilee Fields, a high premium oil[8] which sell between $110-122 per barrel in Europe and $105-110 in the United States. Rather, it

[7] CUSUM and CUSUMQ plots for each model are not shown but are available on request.

[8] With API equal or greater than 39. Crude oil differ primarily by factors such as API gravity (a measure of density developed by the American Petroleum Institute with the API gravity index ranging from 21 to 44), location and sulphur content (ranging between 0 to about 3%). Lower sulphur content and higher API density of crude command higher premiums over higher sulphur content and lower API density index (Keynote address by William Nordhaus at the International Energy Workshop, Venice, Italy on June 17-19, 2009.

sounds more prudent to use part of Ghana's proceeds from the sales to mitigate the impact of consequential high product prices at home." This was against government's forecast of average crude oil price of $93 per barrel Ghana would pay for her crude oil imports from Nigeria and Equatorial Guinea.[9] Interestingly, import demand for crude oil responds significantly positive to oil price in the short-run in all models estimated (see Table 5). The result is significant for both the current and one-period lagged estimates of international crude oil price in models (1)-(4). Consistent with the long-run results, all the estimated coefficients of oil price are inelastic in the short-run, ranging between 0.62-0.79 for the current period price and 0.23-0.34 in the case of a one-period lag in oil price. The price inelastic estimates with respect to import demand for crude oil implies that changes in oil prices do not have a big effect on crude oil demand in Ghana. The reported positive nexus may sound rather counter-intuitive and theoretically inconsistent. However, in the context of Ghana's crude oil demand dynamics, this could be due to lack of close substitutability for crude oil in meeting Ghana's surging energy demand for industry, transport, business and domestic purposes. Thus, Ghana's demand for crude oil may increase regardless of the world oil price, at least in the short-run. Another explanation could be adduced to the hedging policy adopted by the government in recent times to mitigate the effects of volatility in the price of crude oil on the international commodity trading market. Thus, in periods where the hedged price is below the prevailing international crude oil price, Ghana can have the breather to accommodate higher import of crude oil irrespective of higher market prices.

Not surprisingly though, we find that the dominant driver of high import demand for crude oil in Ghana is the level of economic activity in both the long-run and short-run. All the estimated coefficients of real economic activity in models (1)-(4) are positive and statistically significant at the 1% level. Thus demand for crude oil in Ghana is income elastic in either period under consideration. The estimated elasticities of oil imports to income in the long-run implies that ceteris paribus, an increase in real income of the economy would stimulate real economic activities in energy dependent sectors of the economy such as transport, mining, agriculture and industry and hence increase demand for crude oil. For example, an increase in real GDP by 1 percentage point would increase oil imports by 1.6%, 2.06%, 1.97% and 2.63% in the long-run, given by models (1)-(4) respectively. Thus sluggish growth of the economy could depress demand for crude oil. Not surprisingly, Ghana's rapid economic growth in recent years is correspondingly associated with ballooning crude oil import bills. The rather large magnitudes of the income estimates are not inconsistent with the literature. Ghosh (2009)

[9] This forecast was made in 2010.

obtained an income elasticity of imported crude oil to be 1.97 for India. Similarly, Narayan and Smyth (2007) found an income elastic demand for oil in 7 out of the 12 Middle East countries considered in their study and an income elasticity of 1.014 for the entire panel. Oil is much more of a luxury commodity in the developing world including Ghana, where oil is either used as a source of domestic fuel or to fuel private cars which dominate public transportation. The reverse is the case in the developed world, where people bike or join public transport. Corroborated by findings from Altinay (2007), Sa'ad (2009) and Ziramba (2010) among others, we find short-run real economic activity elasticity to be inelastic in the short-run (see models 1-4 in Table 6). Specifically, our estimates reveal highly significant real GDP elasticities of 0.52, 0.996 and 0.84 in models (1)-(3), respectively. Albeit with a theoretically incorrect negative sign in model (4), the effect of real GDP on crude oil demand is statistically insignificant.

The role of the real effective exchange rate in the determination of real crude oil demand has received little attention in the literature. Apart from Askari and Krichene (2010) who explicitly included nominal effective exchange rate in their world crude oil demand model to account for monetary policy effects, no other study in the literature on crude oil import demand allows for exchange rate effects in their model. The growing literature on the nexus between world oil price and the US dollar continues unabated. Since crude oil is priced on the international financial and commodity markets, the performance of the US dollar against international bilateral currencies would have an impact on the price of oil and hence demand for crude. For example, depreciation of the US dollar implies oil becomes relatively cheaper in local currency terms for consumers in say Ghana, which could spur import demand for crude oil. Also, a depreciation of the US dollar implies that oil supply countries such as Nigeria where Ghana imports most of her crude oil from where the exchange rate (and hence oil revenues) are pegged to the US dollar, could counteract the depreciating dollar by either increasing the price or cutting back supply which in turn leads to an increase in the price of crude oil. Conversely, a real effective exchange rate depreciation of the US dollar would stimulate real economic activities and hence crude oil demand through its wealth effect arising from non-dollar denominated financial assets (Askari and Krichene, 2010). The preceding reasons could be plausible enough in explaining the effect of the REER variable in our real oil import demand models. For example, results in the long-run (models 2, 3 and 4) show that real appreciation of the Ghanaian currency against the US dollar stimulates demand for crude oil with an inelastic effect. In contrast, only the lag effect of the REER significantly influence oil import demand in the short-run, albeit negatively.

We further investigate whether domestic oil production could substitute for imported crude oil. Even though commercial oil production could significantly reduce dependence of Ghana on foreign oil sources in the long-run, the real answer remains an empirical and policy issue. Nonetheless, we do not expect to see a dominating effect of domestic oil production over the other determinants in our model. On the basis of data, domestic production of oil has virtually stagnated between 2,000-4,000 barrels per day over the period 1980-1995, before increasing to 9,000 barrels per day by 2004. From a low base of 8,000 barrels per day in 2010, discovery of commercial oil reserves resulted in upstream production increasing to some 80,000 barrels per day (short of the initial expectation of 120,000 barrels per day) in 2012. It is important to re-emphasize again that almost all oil output is exported while imports continue to surge. Our estimates show via models (3) and (4) in Tables 5 and 6 that domestic oil production could potentially substitute for oil imports in both the short and long term. However, it is only significant if we account for all potential determinants of oil imports in both periods (model 3 in Tables 5 and 6). The magnitude of the estimated coefficient in the short-run of -0.099 indicates that the effect of increased oil production is almost negligible and with transient effect in the short term. An increase in domestic production of oil by say 10% would depress import demand for oil by only 0.9%, ceteris paribus. In the long-run, however, the effect is much stronger though still inelastic (-0.232).

Finally, population growth could spur demand for crude oil in Ghana. Annual growth rate in population is only marginally significant (10%) and positive in the short-run. Perhaps, the urban growth rate could be a better variable than population growth. However, its inclusion in series of trial models did not significantly improve the results, with population growth giving much plausible estimates.

Table 5. Long-run elasticities

	Dependent variable: $\ln OilM$			
Models	(1)	(2)	(3)	(4)
C	-13.349	-19.684	-13.695	-25.342
	(-4.80)***	(-5.54)***	(-1.70)	(-5.18)***
$\ln OilP$	-0.277	-0.332	-0.161	-0.451
	(-1.40)	(-2.02)*	(-0.70)	(-2.23)**
$\ln GDP$	1.638	2.055	1.970	2.632
	(5.36)***	(7.93)***	(3.78)***	(6.15)***
$\ln REER$		0.428	0.490	0.669
		(2.52)**	(1.86)*	(2.54)**
$\ln OilPrd$			-0.232	-0.126
			(-1.82)*	(-1.45)
POPG		0.143	-1.819	
		(0.28)	(-1.39)	

Note: ***, ** and * denote significance at the 1%, 5% and 10% levels respectively. Values in parenthesis, (), are t-statistics.

Table 6. Short-run elasticities

	Dependent variable: $\Delta \ln OilM$			
Models	(1)	(2)	(3)	(4)
$\Delta \ln OilP$	0.660 (4.82)***	0.621 (5.21)***	0.791 (5.50)***	0.749 (6.74)***
$\Delta \ln Oilp_{t-1}$		0.232 (1.79)*	0.235 (1.94)*	0.344 (2.88)***
$\Delta \ln GDP$	0.524 (2.53)**	0.996 (3.79)***	0.844 (2.54)**	-1.483 (-0.99)
$\Delta \ln REER$		-0.090 (-0.98)	-0.073 (-0.79)	-0.10335 (-0.88)
$\Delta \ln REER_{t-1}$		-0.364 (-4.29)***	-0.353 (-4.36)***	-0.333 (-4.35)***
$\Delta \ln OilPrd$			-0.099 (-2.12)**	-0.058 (-1.49)
$\Delta POPG$		0.814 (2.02)*	-1.690 (-1.15)	
$\Delta POPG_{t-1}$			2.076 (1.83)*	
ECM_{t-1}	-0.320 (-3.59)***	-0.485 (-4.99)***	-0.428 (-4.5773)***	-0.465 (-5.67)***
	Regression statistics and diagnostic tests			
R^2	0.730	0.852	0.879	0.861
$\overline{R}^2$	0.681	0.774	0.798	0.788
F-Stat.	19.8631[0.000]	15.626[0.000]	14.492[0.000]	16.833[0.000]
DW-statistic	1.98	2.46	2.55	2.27
Serial correlation: χ_{SC}	0.007[0.979]	2.204[0.138]	3.736[0.053]	1.098[0.295]
Functional form: χ_{FN}	0.481[0.488]	3.888[0.049]	3.777[0.052]	2.883[0.090]
Normality: χ_{N}	7.648[0.022]	0.134[0.935]	0.403[0.817]	1.577[0.455]
Heteroscedasticity: χ_{HET}	0.072[0.789]	0.607[0.436]	0.004[0.984]	0.078[0.778]
CUSUM/CUSUMQ	Stable	Stable	Stable	Stable

Notes: ***,**,* denote statistical significance at the 1%, 5% and 10% levels, respectively. Optimal ARDL model selected based on SIC. Values in parenthesis () and [] are t-statistics and p-values, respectively.

5. Conclusion and policy implications

In the absence of any study on Ghana's demand for imported crude oil, this is the first study that empirically estimates factors accounting for import demand for oil. We use the ARDL cointegration approach by Pesaran *et al*. (2001) to test for existence of long-run equilibrium relationship between real import of crude oil and real oil price, real economic activity, real effective exchange rate, domestic oil production and population growth. Following confirmation of long-run equilibrium existence, we isolate these effects by estimating the long-run and corresponding short-run models. Our results show that while import demand for crude oil is price inelastic in both the long and short run, the story is different for real economic activity. While the price elasticity estimate is theoretically consistent in the long-run (i.e. negative), the reverse is found in the short-run. Specifically, an increase in real oil price significantly stimulates crude oil import. The inelastic oil price elasticity implies the lack of diversified energy substitutes or alternatives. Thus on the policy front, government could generate more tax revenue on crude oil products, given the inelasticity of demand. It is however important to take into consideration the welfare implications of the tax on the poor consumer.

Other interesting results show that demand for crude oil is income inelastic in the short-run but highly income elastic in the long-run albeit significantly positive in all cases considered. Furthermore, real effective exchange rate is a significant driver of crude oil import demand in both long and short run periods. While the effect is positive and significant in the long-run, only the one-period lag effect is significant and negative in the short term albeit inelastic in each case. This means that monetary and fiscal policy outcomes that strengthen the domestic currency against the US dollar are highly recommended and should be pursued with significant caution. This is because continuous appreciation of the local currency against the US dollar could spell doom for the now oil economy arising from the so called "Dutch Disease" syndrome. The potential effect of domestic crude oil production substituting for heavy dependence on overseas crude oil should be considered. Our results suggest that Ghana could reduce its heavy crude oil import bill if we increase domestic production. With output potential of the Jubilee Fields projected to increase in the foreseeable future, government should re-think its policy on exporting the entire lifted crude oil outside of the shores of Ghana by gradually sourcing its crude requirements from the Jubilee Fields for refinery and electricity generation among other end uses. The role of population growth can also not be underestimated in the dynamics of crude oil demand in Ghana.

Lastly, from an overall policy perspective, government should assiduously invest into alternative and cleaner sources such as wind energy, solar panels, biofuel among others. Improvements in the unreliable and inefficient public transportation system are inevitable. Mass rapid bus transportation and a modernized rail system would significantly reduce over-dependence on private vehicles by households. The impending gas processing project in Ghana should be expedited to harness the production potentials of gas and to curtail the current practice of gas flaring.

Overall, energy efficiency and conservation, and public education are critical elements that can reduce the huge import bill of crude oil and its associated effect on the foreign reserve, export earnings, fiscal deficit, BOP position and the trade-off between resources used to meet crude oil demand and other sectoral development (such as agriculture, manufacturing, education, health, etc.) of the economy.

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Appendix

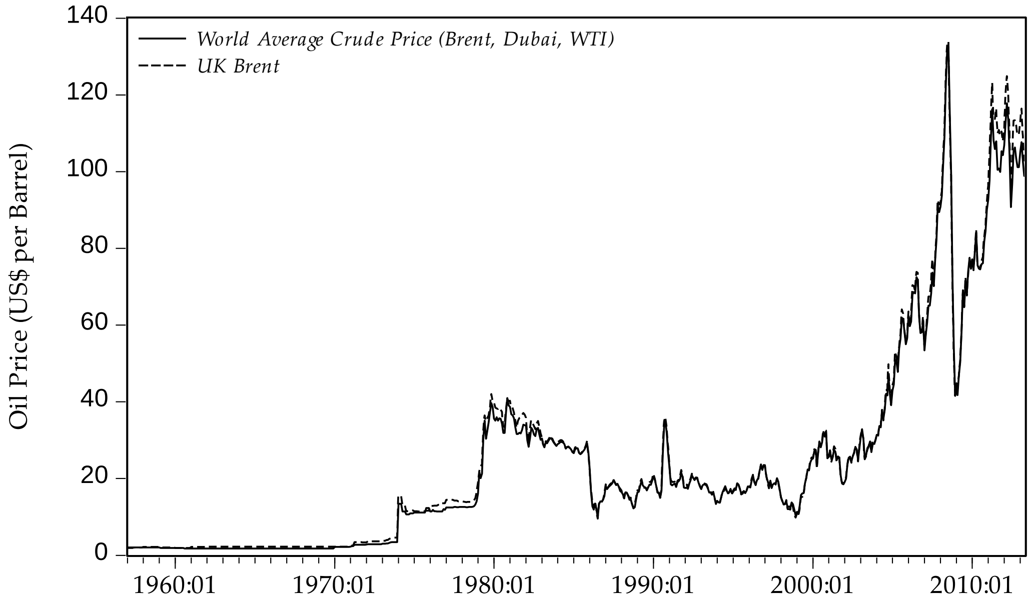

Fig. 4. Trends in Global Petroleum Price
Data source: International Financial Statistics, IMF

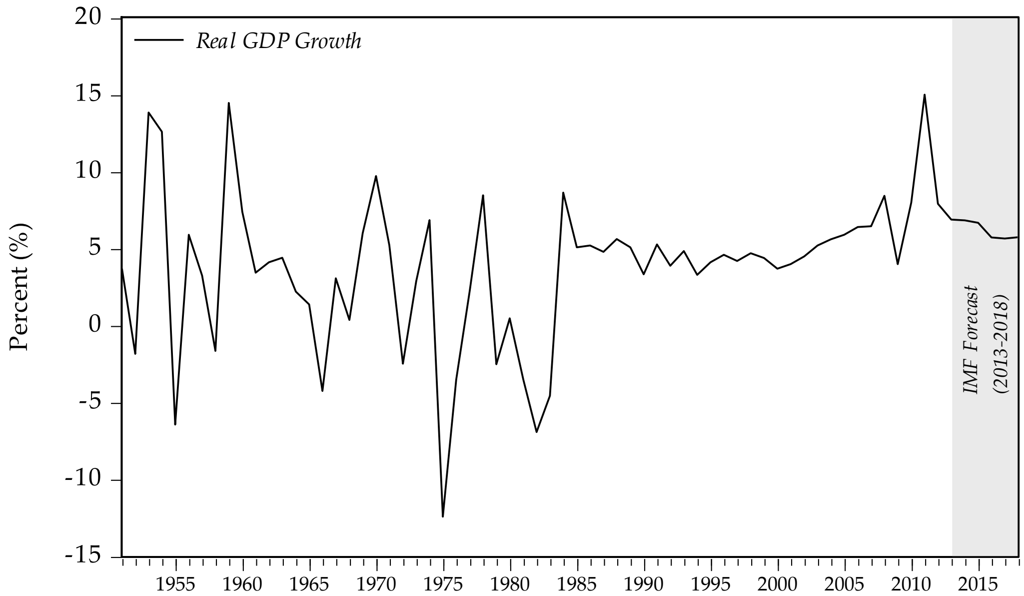

Fig. 5. Evolution of Economic Growth in Ghana
Data source: Ghana Statistical Service; World Development Indicators; Fiscal Affairs Dept. Database, IMF.